Weather Note

VISUAL OBSERVATIONS BENEATH A DEVELOPING TORNADO

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We had the remarkable experience of viewing a developing tornado funnel as it passed nearly overhead. Our location was a radar site about one-half mile east of Tinker Field, Oklahoma City, Okla.; the time, about 1620 CST, May 26, 1963.

The earliest report of the funnel was given by the Tinker Field weather observer, 2 miles west-northwest of our location, at 1616 CST. He estimated the funnel base to extend down to 1600 ft. above the ground.

A few minutes after our observation, at 1627 CST, moving pictures of the funnel cloud were taken by Maj. James F. Church, also of AFCRL, from a point 5 miles or more to its west. Because of the great distance and the very poor contrast between the dark clouds forming the background and the slightly darker funnel cloud, detail was almost entirely lacking. However, the movies show clearly that the funnel was very broad, with an apex angle of about 80°, and the tip had not yet reached the ground. The funnel axis was not quite vertical, tilting about 10° toward the north from bottom to top.

The movies by Maj. Church show the funnel east of our location, but probably a mile or so west of the earliest severe damage, which occurred very near 1630 CST. There was no damage at our location. Minor damage to trees started 1.5 mi. east of our site, and major tornadic devastation occurred along a path 3.5 to 7.5 mi. east of our location.

Figure 1 is a radar photograph of the storm as it was observed by WSR–57 radar within a minute or two of our visual observation of the tornado. This radar picture was taken from the U.S. Weather Bureau Radar Laboratory at Norman, Okla., about 11 n. mi. south of our observing site. It shows a hook echo, which is sometimes observed in association with tornadoes, protruding from the right rear (or southwest) side of the storm. The antenna beam was elevated 2.5°. Most of the echo power was returned from the cone defined by the half-power beam width of 2°, or from a layer 1800 to 4100 ft. above the ground at a range of 11 mi. The tornado which we sighted was located near the eastern edge of the hook echo, and toward its southern extremity.

We first noticed the rotating funnel cloud as we were driving toward the radar site. It appeared to be located a short distance east of a region of pronounced, nearly spherical, mammata protruding downward from an indistinct cloud base. Figure 2 shows the relationship of the tornado to these clouds, with our observing position, X, and tornado location, O, given a subscript 1. From position X_1 we could see a relatively clear space to the south and we could see the eastern edge of the unusually well-developed mammata behind the tornado, and extending considerably less than a mile south of it. Also, the mammata had been noted previously when we were 2 miles north of the tornado track. However, we were unable to observe the greatest extent of the mammata region to the north and west of the tornado. Although our vision was not obscured by any heavy precipitation falling beneath the mammata, at least near the eastern edge, we cannot state whether or not some indiscernible precipitation (light rain or hail) was falling there or whether heavier precipitation was falling farther to the west and north. We did not look toward the east of position X_1, so we cannot state what clouds were in that area.

A comparison of figures 1 and 2 reveals a general correspondence between the hook echo and the area of mammatiform cloud base.

The best observations of the structural detail of the funnel were made from position X_2, with the developing tornado at O_2 passing slightly to the north. However, the menacing appearance of the rotating cloud mass prevented us from noting or remembering any significant features of the surrounding clouds. We did observe, however, that there was no precipitation, and that surface winds were quite strong from the southwest, estimated by both of us to be in the neighborhood of 50 to 70 kt. For a period of perhaps one-half to one minute one of us (WEL) was engaged, with difficulty, in trying to gain admittance to the sturdily-built radar operations building, since we feared the imminent appearance of dangerously destructive winds at the ground. Meanwhile, the other (RJD) divided his attention between anxious concern for survival and fascinated observation of the developing tornado. We had no camera or other instruments available. Therefore, quantitative aspects of the observations cannot be stated with any greater certainty than a factor of two,

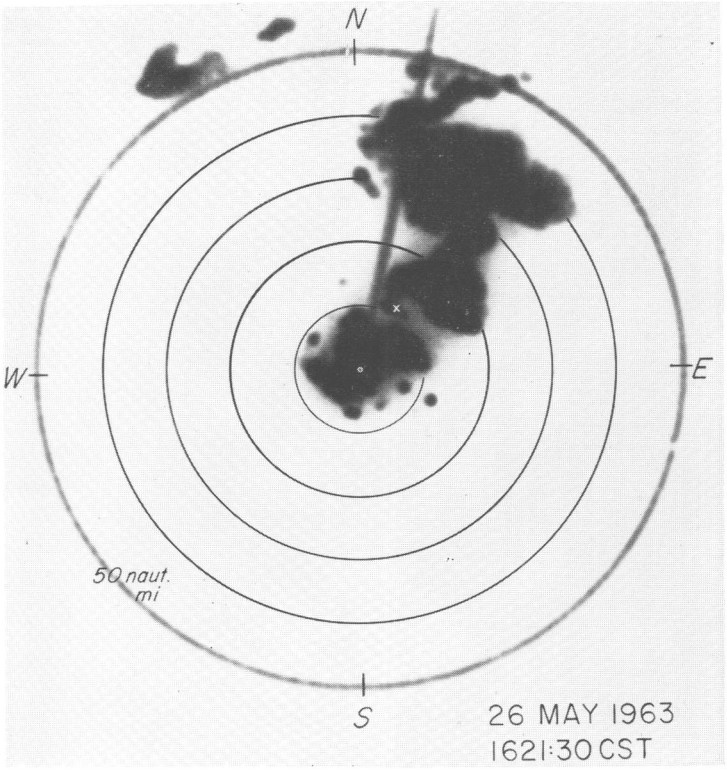

FIGURE 1.—Radarscope photograph of tornadic thunderstorm echo at time of visual observation of developing tornado, at location marked "X". Antenna elevation is 2.5°, and receiver sensitivity is reduced 18 db. below maximum. This photograph was taken on the PPI (plan view) scope of the WSR-57 radar at Norman, Okla., operated by the U.S. Weather Bureau Radar Laboratory, and was furnished by courtesy of Mr. C. F. Van Thullenar, Director, National Severe Storms Project.

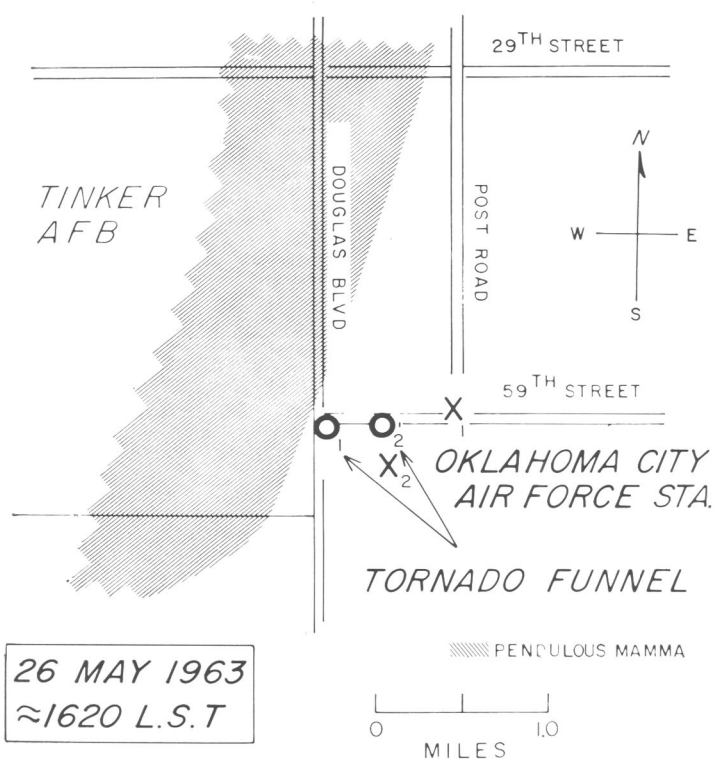

FIGURE 2.—Estimated positions of developing tornado (O_1 and O_2) observed from positions X_1 and X_2, respectively, separated by about one minute. The hatched area is the approximate location of a region of pronounced mammata observed from position X_1 which trailed behind the funnel cloud a short distance and to its north. The ragged edge of the hatched area indicates uncertainty about the maximum westward and northward extent of the mammata region.

although we are confident of the general qualitative picture.

The tornado funnel was viewed approximately end-on (along the axis of rotation) as it passed slightly to the north of our position. It consisted of a circular area of dark clouds projecting downward from a background of lighter clouds. Since the funnel was nearly overhead it was not possible to determine whether it was cylindrical or a truncated cone.

The outer boundary of the funnel was smooth, unbroken, and definitely circular in cross section. However, there was no well-defined inner wall and no visible evidence of a hollow space inside the funnel. Instead, the region inside the solid outer boundary was filled with a patchy cloud structure, similar to scud fragments. The pattern of patchiness did not have circular symmetry and it seemed to change rapidly, as if there were extreme turbulence moving the patches about relative to one another, as well as generation of some new cloud fragments and destruction of some others. Superimposed on all this turbulent activity, however, was a very regular clockwise (seen from below) or cyclonic rotational motion of the whole funnel, which appeared to have constant angular velocity throughout except near the center where turbulent motions masked the rotation. No lightning or luminous glow was seen. There was no roar. The only sound we heard was the whistling of the surface gales.

Rough estimates were made of certain funnel characteristics. These are judged to be trustworthy within the stated limits:

(1) The rotational period was 2 to 4 sec.

(2) The angular diameter subtended by the funnel was somewhere between 10° and 20°.

(3) The height of the funnel cloud above the ground was between 500 and 2000 ft. This dimension was especially difficult to estimate; furthermore, the cloud fragments toward the center of the funnel appeared to be lower than the periphery.

(4) The impression of solid rotation was strong in all parts of the funnel except in an area near the center which had a radius of about 0.1 to 0.3 of the funnel radius, in which the rotational component was obscured by the turbulent motions.

The mean of these estimates implies a funnel diameter of 330 ft. and peripheral speed of rotation of 205 kt. These are within the range of expected values, but no

better accuracy than a factor of two is implied. Turbulent motions of a random direction superimposed on a steady rotational velocity of the same magnitude or less would present a confusing appearance. Since the cloud motions were confused in the central core of the funnel, out to an estimated average fractional radius of 20 percent, the best guess for the mean magnitude of the turbulent component of velocity is 40 kt.

A sudden drop in surface atmospheric pressure also accompanied the funnel cloud. Just before entering the radar operations building we observed, through a window in the closed door, many fine particles like insulating material flying about inside the building. We believe that these particles were separated from the interior walls and ceiling of the building by an intense atmospheric pressure gradient. The strong southwest winds were still blowing at this time. Also, we learned later that many steel plates (approximately 40 in. x 24 in. x ½ in.) covering the exterior cable ducts were popped off, presumably by sudden pressure drop because only the thin edge is exposed to the wind. According to hearsay evidence, the latter event also occurred during high southwest winds, several seconds before a short period of calm, which was followed in turn by strong winds from the northwest. Unfortunately, no barometric or wind measurements were available. However, the two bits of evidence indicate the occurrence of a maximum pressure gradient at least a few seconds before the wind calmed.

In summary, the most striking features of our observation, which we also believe to be most reliable, are: (1) the location of the tornado a short distance east of pronounced mammata; (2) approximately constant angular velocity of cloud fragments throughout the funnel in combination with violent turbulent motions which were, however, considerably less than peripheral funnel speed; and (3) high surface winds continuing for at least several seconds after the occurrence of a sharp maximum in the gradient of falling atmospheric pressure.

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UNUSUAL TORNADO PHOTOGRAPHS

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In years past, the obtaining of a photograph of a tornado in action was a rather rare event. In more recent times, individual tornado photographs became more commonplace and sequential pictures of a tornado became the prized item. At present, as a result of the increased population and the universal popularity of amateur photography, multiple serial photographs of single tornadoes are not uncommon, at least in meteorological research circles. Currently, particular phases of the tornado sequence become the rare photograph.

The beginning tornado has rarely been photographed simply because the photographer, amateur or professional, has not known whether or not a tornado was going to develop from a storm or, generally, from what part of the storm it might come. Two very unusual beginning tornado pictures recently came to the attention of the writer. They were taken in color by Mr. C. Y. Byrd, III, of Tampa, Fla., on July 28, 1963, and were submitted by Mr. L. M. Dye, of the Weather Bureau Office at Tampa.

These photographs (figs. 1a, b) are shown in the order in which they appear to have been taken. The central lobe and circular cloud bands definitely suggest rotation of the cloud system. The degree of ellipticity, assuming that the bands were truly circular, suggests that the formation was nearly overhead when the initial photograph was taken. Mr. Dye describes the event, as follows, in a letter sent with the pictures:

"The storm from which this tornado developed was moving westward across the land area of the City of Tampa known as Palm Ceia, which is a strip of land between Hillsborough Bay and Old Tampa Bay. The funnel cloud had not touched the ground when the pictures were taken. Just before the pictures were taken the sun was shining. The funnel cloud touched the ground shortly after the pictures were taken and traveled in a northeast-southwest line toward the southwest. Rain began shortly after he took the pictures and prevented Mr. Byrd from seeing the tornado. The rain at Mr. Byrd's home lasted only 3–4 minutes. He stated that the main part of the storm was north of him. From a survey made, the damage consisted of 2 roofs damaged on houses; a few trees down, some falling on cars; and some damage to an outdoor laundry. Total damage was estimated to be $10,000."

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